

# A circularly polarized Ka-band stacked patch antenna with increased gain

Mark Zawadzki

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, CA 91109

## Introduction

There has been recent interest at NASA and the Jet Propulsion Laboratory in developing an antenna system at Ka-band for use in future deep-space missions. For an equivalent 3-meter aperture, switching to Ka-band not only means a 6dB improvement in gain over the current X-band systems in use today, but it also implies an increase in the data rate for transmitting scientific data back to Earth. A drawback of the Ka-band antenna is that its narrow beam ( $\approx 0.2^\circ$ ) can point away from the Earth as the spacecraft position vacillates during flight. This slight fluctuation, which is about  $1^\circ$ , is not an issue at X-band because the beam is broad enough to provide adequate coverage regardless of the wobble. In the proposed system, the beam would be electronically steered back to Earth using data from the spacecraft's attitude control system. An antenna configuration that can provide vernier scanning of the main beam is the near-field dual-reflector antenna. By placing the subreflector in the near-field of a phased array feed, limited scanning in the far-field of the main reflector can be effected. Certain design criteria necessitated the use of a fairly directive array element. The element developed for this purpose was a multi-layered microstrip antenna with relatively large spacing between layers to increase the effective aperture size and element gain (similar to a Yagi).

Stacking layers of microstrip patches is a technique often used to improve the bandwidth of a patch antenna, but rarely used to increase its gain. Previous work to enhance the gain of a three-layer linearly polarized stack reported a gain of 10.6dB<sup>[1, 2]</sup>. Circular polarization (CP) using a two-layer stack was first reported in [3]. A three-layer CP stack was reported in [4] and showed a gain at S-band of 12.2dBic. The work presented here scales the three-layer S-band work done in [4] to Ka-band.

## Antenna Description

An isometric drawing of the three-layer antenna is shown in Fig. 1a and a photograph is given in Fig. 1b. The antenna consists of four 0.13mm-thick layers of PTFE substrate ( $\epsilon_r = 2.2$ ) and two layers of foam ( $\epsilon_r = 1.08$ ,  $t_{\text{lower}} = 4.8\text{mm}$ ,  $t_{\text{upper}} = 3.6\text{mm}$ ) affixed to a 4.75mm-thick brass support plate, which also serves as the ground plane. The total height of the antenna is approximately  $1\lambda$ , not including the brass support plate. The feed line is etched onto the lowest PTFE substrate and is proximity coupled to the driven patch element located on the next PTFE layer above. The foam supports two additional PTFE layers with parasitic microstrip patches, which are electromagnetically coupled to the driven element. The use of proximity coupling assisted mainly in matching to the high input impedance of the three-layer configuration; however, it also likely contributed to improving the bandwidth slightly by allowing the driven patch to exist on a thicker substrate than the feed lines. The wider coupling lines underneath the driven patch helped fine-tune the impedance match to the antenna. A coax-to-microstrip transition was used to feed the two orthogonal transmission lines that proximity-couple to the driven patch of the stacked element. This feed arrangement assumes that a signal with a  $90^\circ$  phase difference is supplied to the two feed lines using a T/R module on the other side of the brass plate. The element was designed using Ansoft Ensemble and was first fabricated at the scaled frequency of 2.56GHz to

### Acknowledgements

The research in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

### References

- [1] R. Q. Lee and K. F. Lee, "Gain enhancement of microstrip antennas with overlaying parasitic directors", *Electronics Letters*, vol. 24, pp. 656-658, May 1988.
- [2] R. Q. Lee, K. F. Lee, and J. Bobinchak, "Characteristics of a two-layer electromagnetically-coupled rectangular patch antenna", *Electronics Letters*, vol. 23, pp. 1070-1072, Sept. 1987.
- [3] R. Q. Lee, T. Talty and K. F. Lee, "Circular polarisation characteristics of stacked microstrip antennas", *Electronics Letters*, vol. 26, pp. 2109-2110, Dec. 1990.
- [4] M. Zawadzki, "A multi-layer circularly polarized patch antenna with proximity coupling and increased gain", 2001 IEEE AP-S Intl. Symp. Digest, vol. 3, pp. 416-419, July 2001.

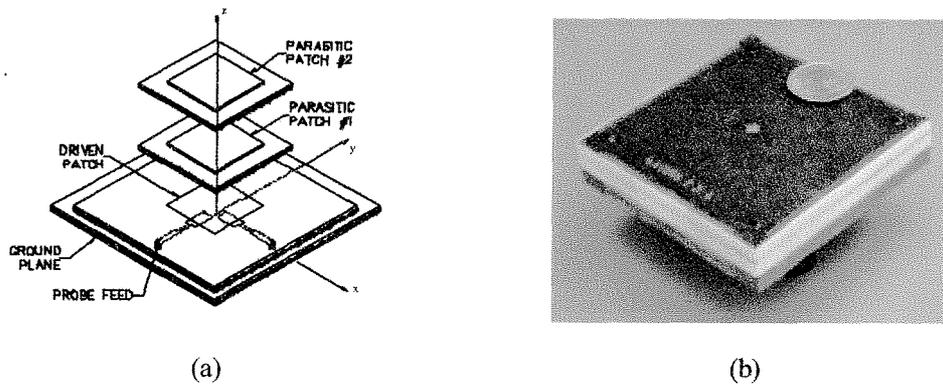


Figure 1. A three-layer circularly polarized Ka-band antenna with proximity coupling

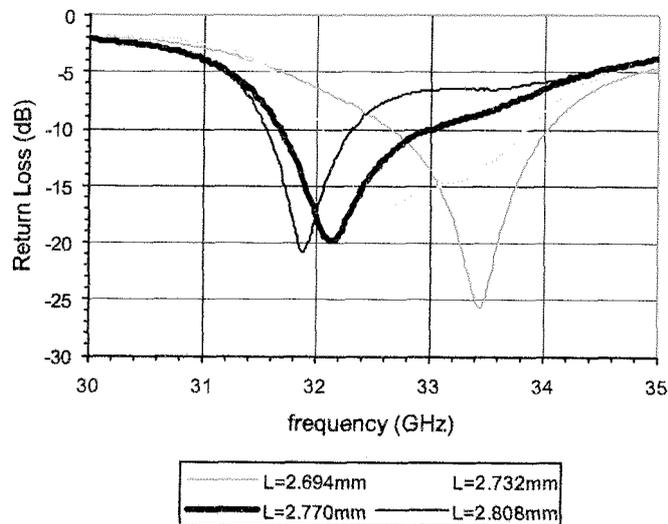


Figure 2. Measured return loss for four different patch lengths

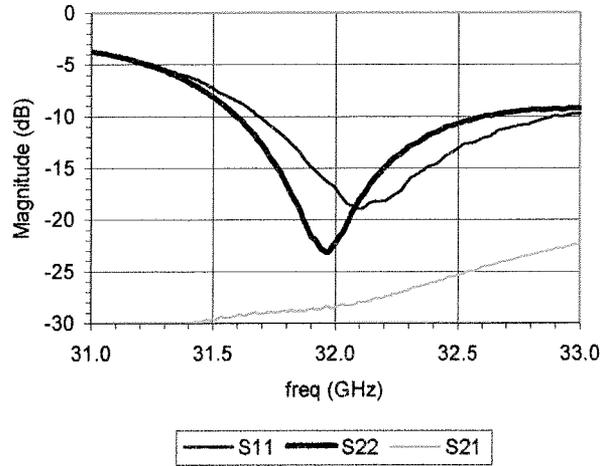
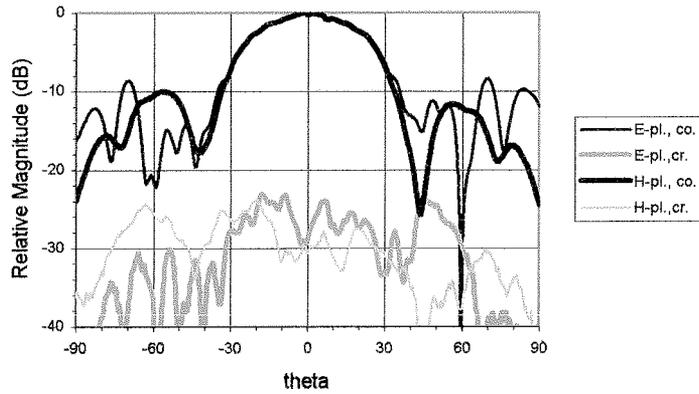
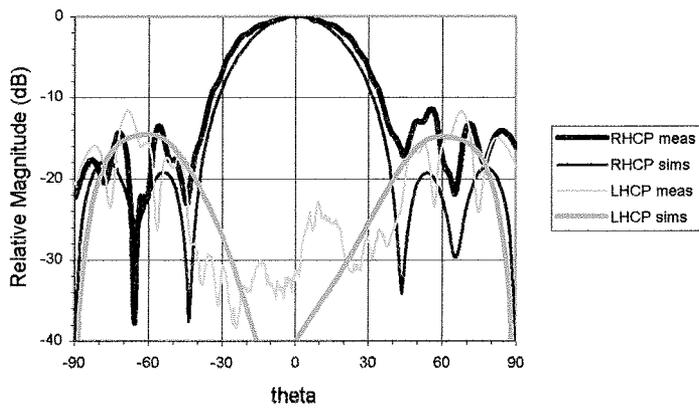


Figure 3. S-parameters for L=2.770mm patch



(a)



(b)

Figure 4. a) Measured patterns with linear polarization.  
 b) CP patterns from measured data compared with simulated results.